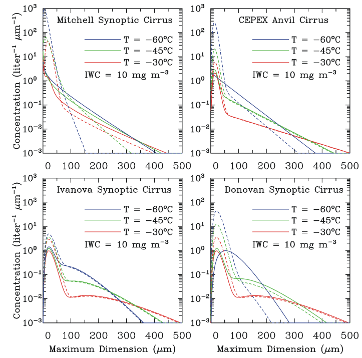
Estimating Cirrus Size Distributions with Help from Satellites

Research Highlight

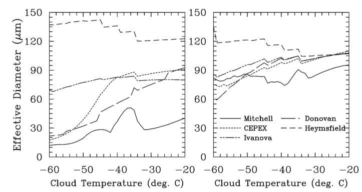
Historical measurements of ice particle size distributions (PSDs) in cirrus clouds have been plagued with uncertainties regarding the concentration of small (D<60 μm) ice crystals, resulting in large uncertainties in PSD mass flux-weighted fall velocities (Vf), cirrus cloud coverage, and estimates of climate sensitivity in global climate models (GCMs). One way to address this problem is to use radiance measurements to characterize the relative concentrations of small ice crystals.

By developing and applying new theoretical insights regarding absorption by ice crystals at 11# and 12-μm wavelengths, satellite remote sensing can be used to evaluate the relative concentration of ice crystals less than ~60 μm. While earlier studies have interpreted the absorption difference between these wavelengths as due to changes in the imaginary part of the refractive index for ice, this study shows it is due to the real part that produces different contributions from wave resonance or photon tunneling. These differences in absorption contributions are only apparent when ice particle sizes are less than ~60 μm, making tunneling an ideal signal for the detection of small ice crystals. Moreover, small ice crystals tend to be quasi-spherical, and tunneling contributions are greater on such shapes.

An average cirrus emissivity relationship between 12 and 11 μm is developed here using the MODIS satellite instrument, which to a first approximation is the absorption optical depth ratio or β. This is used to \"retrieve\" the PSD, based on five different temperature-dependent PSD schemes. The PSDs from the in situ measurement-based PSD schemes are compared with corresponding retrieved PSDs to evaluate differences in small ice crystal concentrations. The retrieved PSDs had lower concentrations of small ice particles, with total number concentration N independent of temperature. Moreover, the degree of PSD bimodality increased with increasing temperature. In addition, the retrieved temperature dependence of the PSD effective diameter (De) and Vf were compared with those calculated from the corresponding PSD scheme (derived from aircraft measurements). These retrieved properties exhibited less variability for a given temperature due to the correction for small ice crystals. Improved estimates of the ice particle mass- and projected area-dimension relationships have also improved our estimates of De and Vf. Because this ensemble temperature dependence for De and Vf has climatological significance, it should be helpful in producing better estimates of climate sensitivity in GCM simulations.



The retrieved mean effective # was found to be 1.065 for thin cirrus having temperatures < -35 C. Based on this value, PSD were retrieved (solid) and compared with corresponding PSD given by the original PSD scheme (dashed). The retrieved PSD have lower concentrations of small ice crystals, with bimodality increasing with increasing temperature.



Comparison of the De-T dependence for the PSD schemes used in this study (left panel) and the corresponding retrieved PSD (right panel). The legend applies to both panels, labeling the 5 PSD schemes used. Adjusting the small ice crystal concentrations to conform to satellite radiance measurements results in much more coherent De-T relationships.

Reference(s)

Mitchell DL, RP d'Entremont, and RP Lawson. 2010. "Inferring cirrus size distributions through satellite remote sensing and microphysical databases." Journal of the Atmospheric Sciences, 67(4), doi:10.1175/2009JAS3150.1.

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Cloud Properties